# Examples of Carter Corrected DBDB-V Applied to Acoustic Propagation Modeling

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The purpose of this report is to describe the difference between nominal depth, as reported in the Naval Oceanographic Office's (NAVO's) Digital Bathymetry Data Base — Variable Resolution, Version 5.1 (DBDB-V v5.1) and true depth, which can be computed from nominal depth (Carter, 1980), and to show the impact of using nominal versus true depth on acoustic propagation estimates.

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# Examples of Carter Corrected DBDB-V Applied to Acoustic Propagation Modeling

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## Abstract

The purpose of this report is to describe the difference between nominal depth, as reported in the Naval Oceanographic Office's (NAVO's) Digital Bathymetry Data Base – Variable Resolution, Version 5.1 (DBDB-V v5.1) and true depth which can be computed from nominal depth (Carter, 1980), and to show the impact of using nominal versus true depth on acoustic propagation estimates.

## Nominal versus True Depth Discussion

Nominal depth (also known as fathometer depth or uncorrected depth) is the depth assuming a constant sound speed through the entire water column of either 1500 m/s or 4800 ft/s (about 1463 m/s). True depth (also known as corrected depth) is the depth accounting for the horizontally stratified layers of sound speed. Strictly speaking, true depth is the product of the harmonic mean sound speed and the one-way vertical travel time of the sounding (Maul, 1970).

In order to supply a geographically applicable correction for nominal depths, Carter (1980) and Matthews (1939) before him, have supplied tables of average sound speed for the world's oceans based on the available measurements. (It should be noted, that Carter's tables are only applicable beyond the natural hydrographic to bathymetric cutoff depth of 200m).

Modern multi-beam and single beam echo-sounding sonars, designed specifically for bathymetric and hydrographic bottom mapping, require better and better field measurements of sound speed and apply, in real-time, the necessary corrections. Due to its lineage in US Navy surface and sub-surface warfare support, DBDB-V is still made up of nominal depths. Future versions of DBDB-V will allow extraction of a Carter corrected true depth. The following illustrates results of these true versus nominal depths to acoustic propagation modeling.

## Comparison of acoustic propagation using nominal versus true depth

As a preliminary example, a random track was extracted from DBDB-V. The nominal depths are plotted in blue and the Carters true depths are in green in Figure 1, the difference between the two (nominal - true) in meters is plotted in Figure 2.

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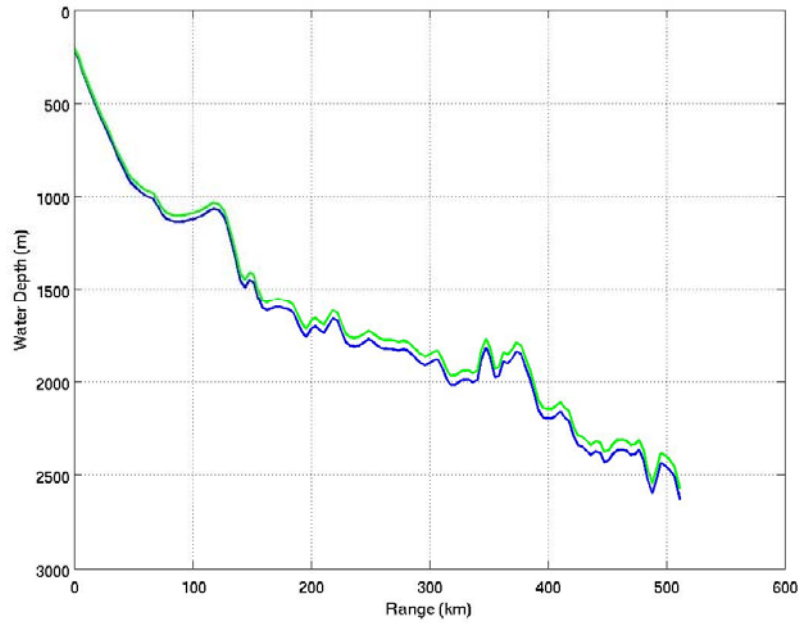
**Figure 1. Nominal depth (blue) and true depth (green) for preliminary example.**
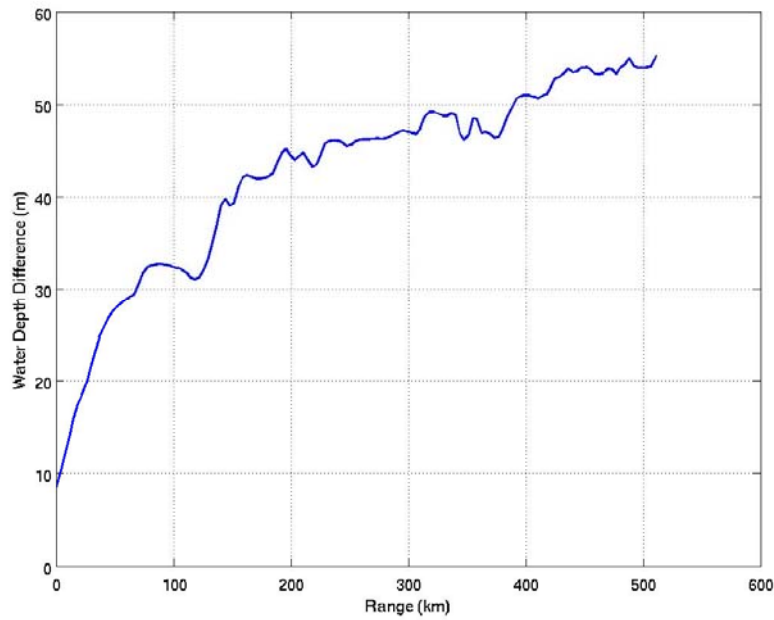


**Figure 2. Difference between nominal and true depth for preliminary example.**

## Detailed acoustic example

For the preliminary example provide above (Figure 1 and Figure 2), the full-field estimate of acoustic TL was generated using the Range Dependent Acoustic Model (RAM) (Collins, 1989) to get an idea of the differences. A source depth of 106m was used with 10 receiver depths, 10, 50, 100, 150, 250, 300, 500, 750 and 1000m. Two cases were run at 100 Hz. Full field TL plots for the track are provided in Figure 3, followed by line plots for 3 receiver depths. The

noticeable differences are in the structure from approximately 500m and below. Comparisons of TL at three receiver depths, 100, 500 and 1000m are shown in Figure 4 and Figure 5. As indicated in the full field plots, the greater differences are at the deeper receiver depths and are significant (~15 dB).
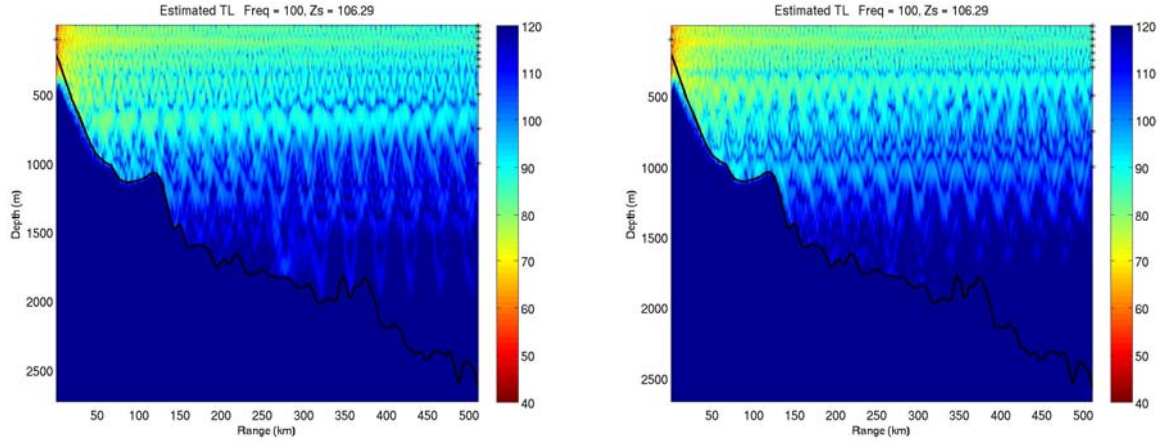


**Figure 3. Full field TL for nominal depth (left) and true depth (right).**
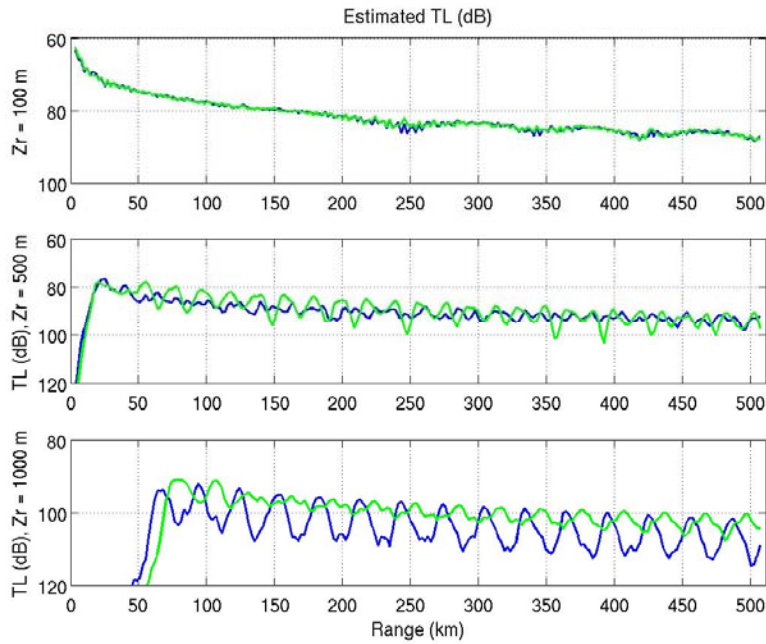


**Figure 4. TL at 3 receiver depths for test case.**

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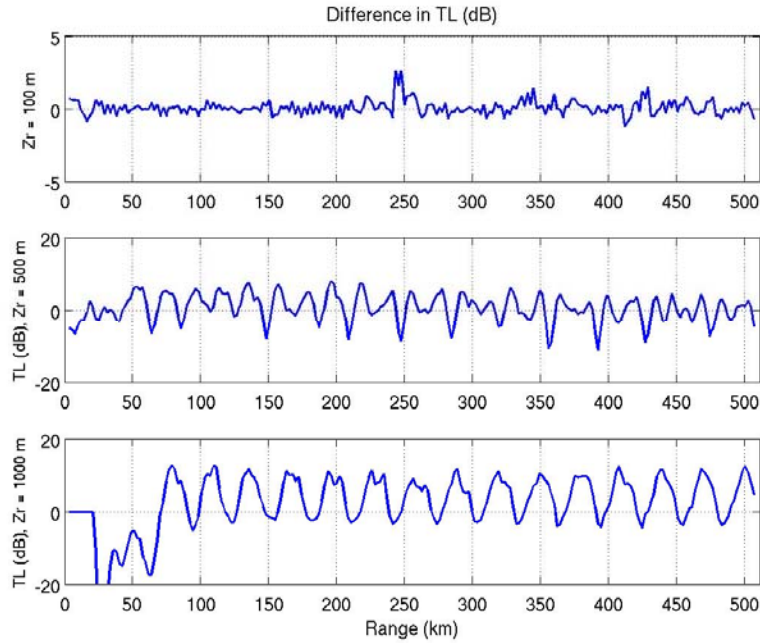
**Figure 5. Difference in TL at 3 receiver depths.**

## Acoustic Impact

To determine the impact of the bathymetric differences on prediction of acoustic propagation for many cases, RAM (Collins, 1989) was used to predict transmission loss (TL) along randomly selected tracks around the world. RAM is a finite element parabolic equation model that is very accurate and is widely used.

The environmental inputs required by the acoustic model include sound speed profile, surface winds, bathymetry and a sediment description. The sound speed profiles were obtained from the Generalized Digital Environmental Model version 3.0 (GDEMV) (NAVO, 2007). The surface winds were left to be 0, and the sediment was set to a single generic sand sediment description for every location.

Two sets of bathymetry and sound speed data were extracted and used for this study. A "shallow" set, representing nominal water depths between 200 and 1200m and a deep set for areas of depth greater than 1200m. Software was written to randomly generate a source location, bearing and month, then bathymetry was extracted along that track to a maximum range of 500km, and if it met the criteria of either of the two data sets it was saved for processing.

The non-environmental inputs to the acoustic model include source and receiver depths and acoustic frequencies. Three source depths were chosen for each track, one at a depth of 10m below the surface, one at half the water depth and the third at 10m above the nominal bottom depth. If the true depth made the water depth shallower than the source, that data set is not used, so there are less data for the deepest source depth. Four acoustic frequencies were chosen, 50, 100, 300 and 500 Hz.

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For each track that was saved, RAM input files were generated and the model was run using the extracted nominal bathymetry and the adjusted true bathymetry (Carter, 1980) for each source depth and each acoustic frequency, resulting in 2 (bathymetry) x 3 (source depths) x 4 (frequencies) = 24 runs per track..


**Shallow Cases**

The shallow test cases included approximately 350 tracks. The differences between the nominal and true (nominal – true) bathymetry for all shallow cases are summarized in Figure 6. Percent occurrence of differences between TL predictions using nominal and true depth were computed for each frequency using center difference values of 1, 2, 3, 4, 5, 7, 10, 20 and 30 dB. The single frequency prediction differences were then sorted into range bins centered on 5, 10, 25, 50, 100, 300 and 500 km. These results are provided in Appendix A. A summary of all sources, receivers, ranges and frequencies into the dB bins is given in Figure 7. In Figure 7 the black line is the summary of all data, the colors represent the three source depths; blue is shallow, green is mid water column and red is deep. This shows more than half the data in the 1 dB difference bin, with the remaining data distributed in the higher difference bins. The mean of the TL dB differences over all cases for 500m range bins over all frequencies, sources and receivers are given in Figure 8. The colors each represent a different source depth, blue is the shallow source, green is the mid water column source and red is the deep source. As can be seen in the figures, the overall mean TL difference is around 1 dB but can be as much as 3 to 5 dB depending on the acoustic configuration. As the frequency increases, the acoustic wavelength decreases, and the propagation is more sensitive to the bathymetry differences. This was evident in the single frequency analysis (Appendix A) by larger mean differences in TL with increase in frequency. In the distribution of differences was fairly even across the various source depths. A summary of results in tabular form is presented in Appendix B.
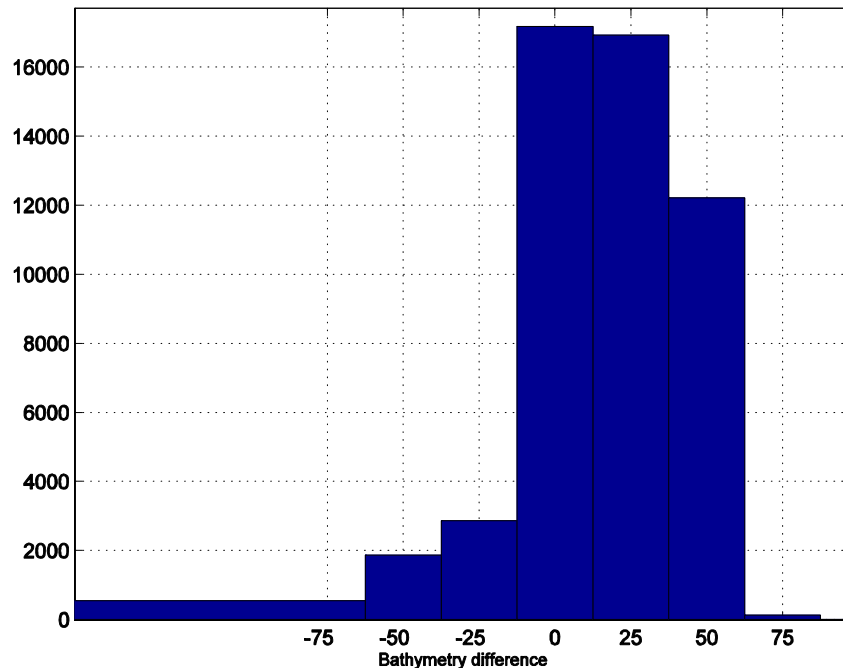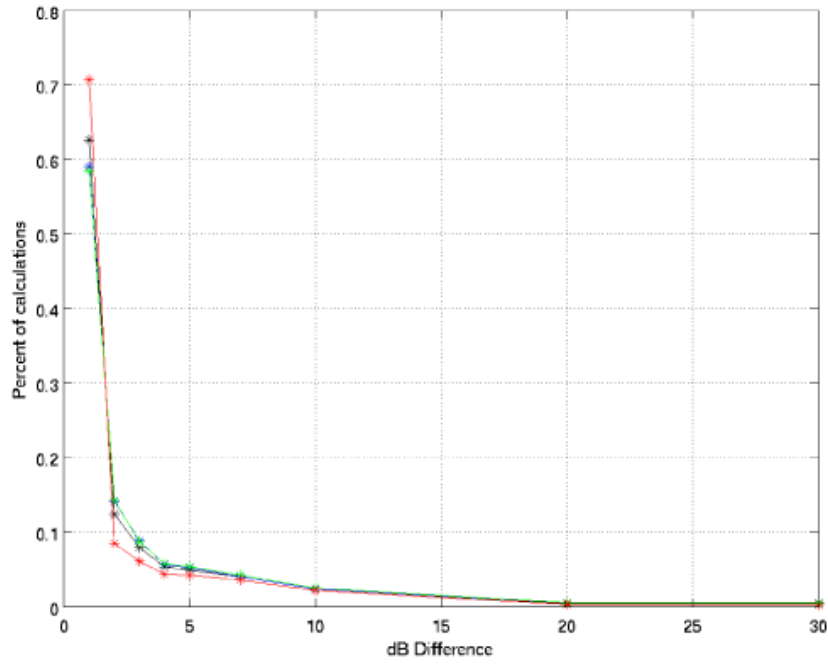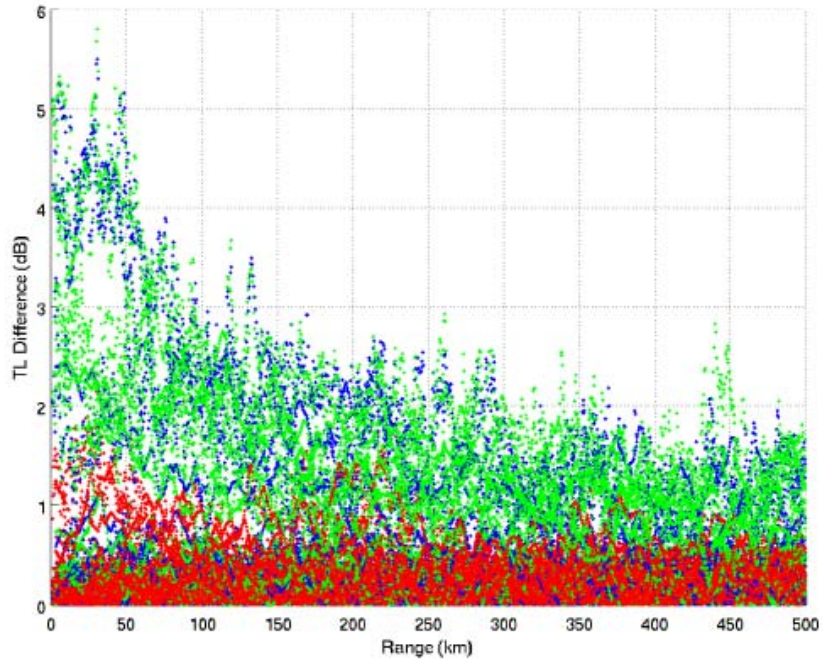


**Figure 6. Histogram of differences between nominal and true bathymetry for shallow data set.**

**Figure 7. Percent occurrence of dB differences for all shallow water cases, all sources, all receivers, all ranges and all frequencies in black, all receivers, frequencies and ranges for each source depth in color (blue, shallow; green, mid-water column; and red, deep).**



**Figure 8. Mean TL difference for all shallow water cases for all receivers and frequencies as a function of 500m range bins. Each source is represented by the colors (blue, shallow; green, mid-water column; and red, deep).**

**Deep Cases**

The deep test cases included approximately 1860 tracks. The differences between the nominal and true (nominal – true) bathymetry for all deep cases are summarized in Figure 9. As before, percent occurrence of differences between TL predictions using nominal and true depth were computed for each frequency using center difference values of 1, 2, 3, 4, 5, 7, 10, 20 and 30 dB. The single frequency prediction differences were then sorted into range bins centered on 5, 10, 25, 50, 100, 300 and 500 km. These results are provided in Appendix A. A summary of all sources, receivers, ranges and frequencies into the dB bins is given in Figure 10. In Figure 10 the black line is the summary of all data, the colors represent the three source depths; blue is shallow, green is mid water column and red is deep. This shows more than half the data in the 1 dB difference bin, with the remaining data distributed in the higher difference bins. The mean of the TL dB differences over all deep cases for 1500m range bins over all frequencies, sources and receivers are given in Figure 11. The colors represent different source depths, as above. As can be seen in the figures, the overall mean TL difference is around 1 dB but can be as much as 3 to 5 dB depending on the acoustic configuration. The single frequency analysis showed the same increase in TL difference with frequency (Appendix A). In this set of deep cases, the deep source showed the highest differences, whereas the shallow and mid source cases were generally clustered below 1 dB.
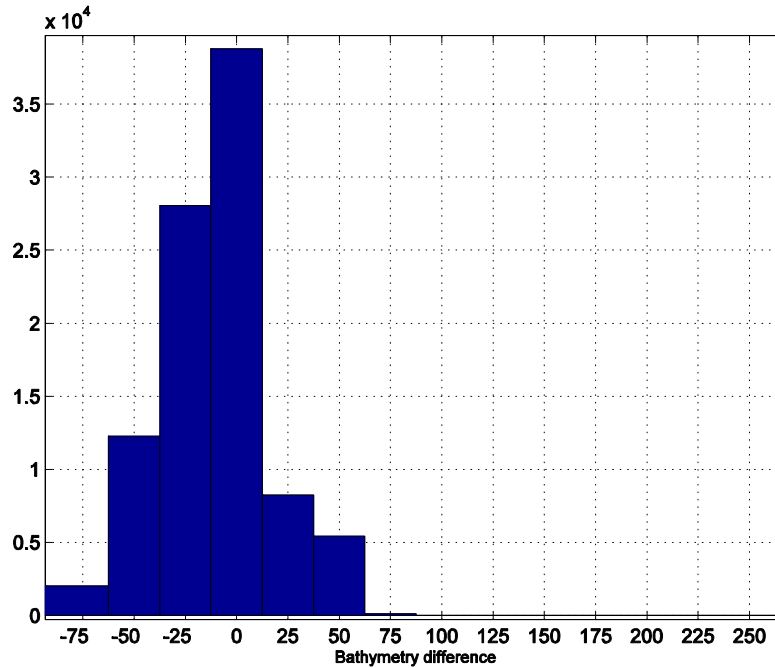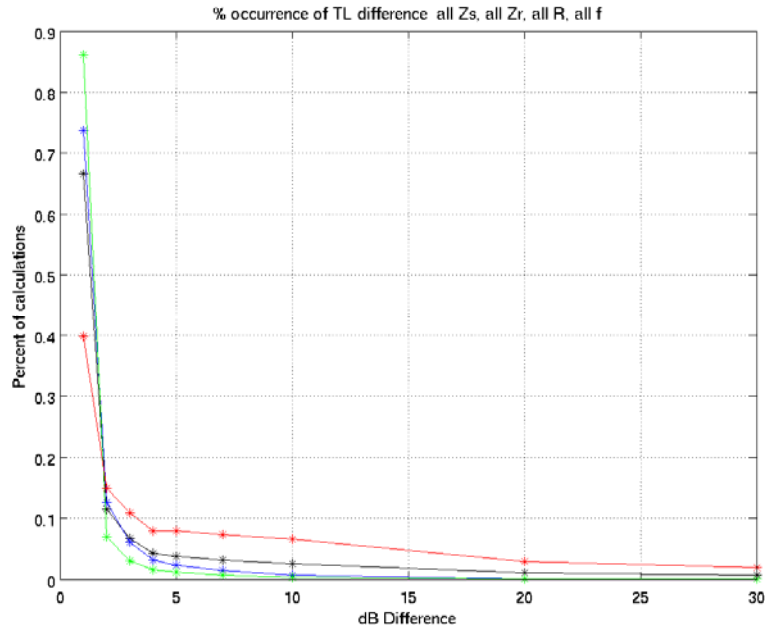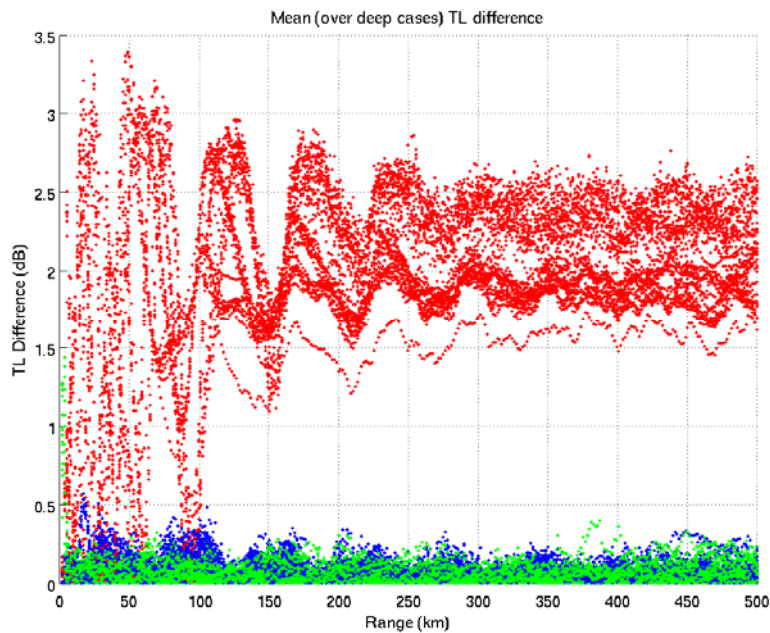


**Figure 9. Histogram of differences between nominal and true bathymetry for deep data set.**

**Figure 10. Percent occurrence of dB differences for all deep water cases, all sources, all receivers, all ranges and all frequencies in black, all receivers, frequencies and ranges for each source depth in color (blue, shallow; green, mid-water column; and red, deep).**



**Figure 11. Mean TL difference for all deep water cases for all receivers and frequencies as a function of 500m range bins. Each source is represented by the colors (blue, shallow; green, mid-water column; and red, deep).**

**Tactical Implications**
In order to demonstrate potential impacts of the use of nominal vice true depth, one example analysis of the acoustic coverage over a wide area was examined.  As described in Dennis and Fabre (2007), acoustic coverage represents the area "seen" by an acoustic receiver due to an acoustic source given a figure of merit (FOM) (Urick, 1983) input by the user. TL was generated for eight bearings at each grid point in an area in the western Pacific ocean using both nominal (extracted from DBDBV5.1) and true (converted from nominal using Carter's tables as discussed above) depths.  Coverage was then computed at every grid point for both scenarios and compared.  The difference in acoustic coverage (nominal – true) for one frequency (~100Hz), one source depth (~100m) and one receiver depth (~100m) are given in Figure 12. The magnitudes of the coverage differences for one frequency, one source and 10 receivers ranged from 0 to approximately 300 km$^2$ with a mean magnitude of approximately 22 km$^2$ with a standard deviation of 22.2 km$^2$, which could be significant. Means for individual receiver depths ranged from 16 to 25 km$^2$ with standard deviations all around 22 km$^2$.
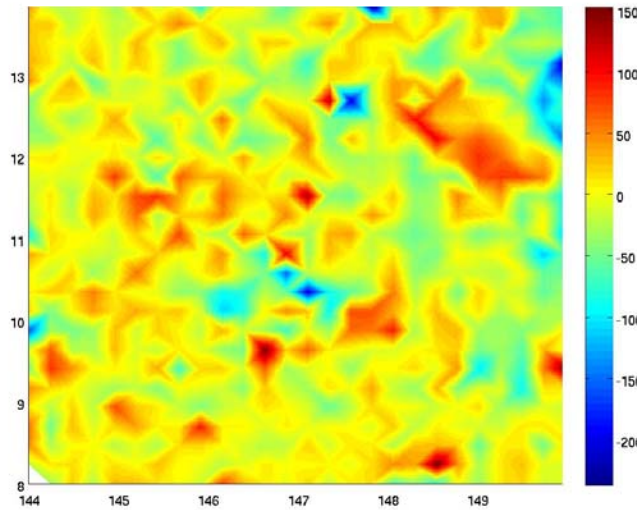


**Figure 12. Difference between acoustic coverages computed using nominal and true depth for an area in the western Pacific ocean.  Color represents coverage area in km$^2$.**

**Conclusions / Recommendations**
Many cases were run to test the impact of using nominal depth (as stored in DBDB-V) vice true depth.  While true depth is the more correct answer, for the cases studied, the impact on more than half of the cases was on the order of 1 dB.  This study used a single sand bottom for all cases and the TL difference could be significantly more given other bottom types.  Additionally, the difference between nominal and true depth will have more of *an* impact on higher frequencies.

Upon examination of acoustic coverage generated using the nominal and true depths, the mean magnitude differences were on the order of 20 km$^2$.
Therefore, it is recommended than in any application where DBDB-V is used to predict acoustic propagation, true depth should be used.  Future versions of DBDB-V will have this as an extraction option.  The Carter algorithm is only used for depths greater than 200m, but the nominal depths are closer to true depths in shallow water.

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